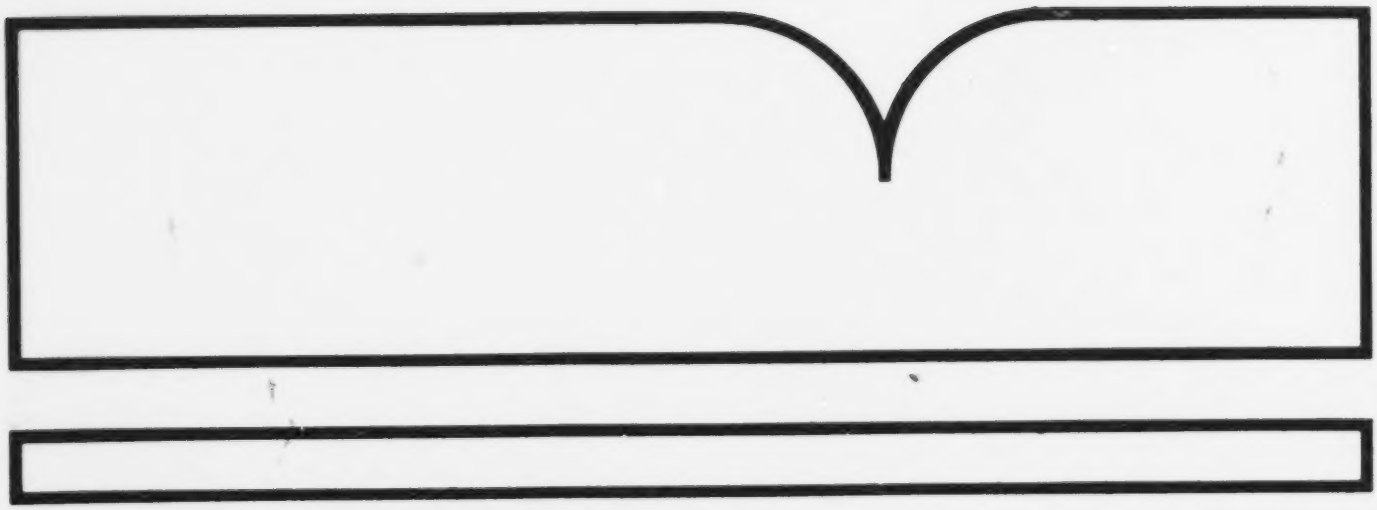
PB83-148478

Evolution of State Codes and Their Implications

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

1982



U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/D-82-365	2. Published Paper	3. RE PB83-148478
4. TITLE AND SUBTITLE Evolution of State Codes and Their Implications		5. REPORT DATE 1982 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) James F. Kreissl		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT NO. AZB1B 11. CONTRACT/GRANT NO. Inhouse
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory - Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final (7/82-8/82) 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES
Presented at 4th Northwest On-Site Wastewater Disposal Short-Course, Seattle, WA (Sept. 21-22, 1982)

16. ABSTRACT

The paper reviews four surveys of state onsite sewage disposal regulations from 1949 to 1980 and identifies the changes and trends of these changes. The physical meaning of various state regulatory requirements are analyzed against the present scientific knowledge. The primary conclusions are that a wide variability exists between state codes, more flexible codes with better trained staffs are more effective, and overly restrictive codes cannot substitute for unskilled personnel.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

18. DISTRIBUTION STATEMENT Release unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 18
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

EPA-600/D-82-365
PUBLISHED PAPER

EVOLUTION OF STATE CODES AND THEIR IMPLICATIONS

by

J. F. Kreissl

Shortly after World War II the Federal Housing and Home Finance Agency and the U.S. Public Health Service initiated a comprehensive study of septic tank-soil absorption system (ST-SAS) technology which included a review of state regulatory codes. This review was published in 1949 (1). This study had historical significance in that it was the first comprehensive review of state codes regulating on-site wastewater systems. The study revealed a wide variety of codified regulations which had developed from varying local experiences. Interestingly, these regulations were extensive with regard to specifications for septic tanks and less specific and more varied with regard to soil absorption systems.

As a result of the publications from Public Health Service study (1)(2)(3) and other studies precipitated by the unsewered housing boom after World War II, the Manual of Septic-Tank Practice (MSTP) (4) was published in 1957. The impact of this document was so significant that a 1971 review (5) of state codes revealed an easily perceptable uniformity with the MSTP.

In 1976, however, another review of state codes revealed that a significant level of code revision was occurring which was resulting in a divergence of codes from the MSTP (6). The causes of these code changes were probably

manifold, but were based primarily on local experiences, new research information and the need to accommodate housing in areas unsuitable for conventional ST-SAS designs.

This discussion is based on the code changes as chronicled in the 1949, 1971 and 1976 surveys and in an unofficial survey conducted by an individual state in 1980 (7). The focus of the discussion is on the trends observed over the past three decades and on the physical meaning of the codified parameters.

SITE EVALUATION AND SYSTEM SIZING

The percolation test has been used for over 50 years as an empirical measure of the suitability of soil for septic tank effluent absorption. Initially, it was devised by Henry Ryon as a measure to be applied to surfacing SAS's and cesspools to determine the maximum allowable loading rates for New York soils. After the tests were run, the lowest loading rate found for failing systems essentially defined the highest loading rate for future designs in soils with that percolation rate.

In the USPHS study (2) a similar analysis was performed which showed similar results, i.e., that for soils with percolation rates between 10 and 60 minutes/inch, allowable loadings should be about 2 percent of the percolation rate.

As the above studies were reported and incorporated into the MSTP(4) and numerous state codes, there was little concern expressed for the fact that the percolation test had no physical meaning and bore no specific relationship to

equilibruim conditions in adsorption systems. It was not until the relatively recent work of Bouma (8)(9) that these shortcomings were scientifically demonstrated.

It was noted in 1949 (1) that fourteen states utilized the percolation test for site evaluation and design. After the advent of the MSTP (4), the 1971 survey (5) revealed that twenty-six states required percolation testing for system design. By 1976, thirty-six of thirty-nine reporting states used the percolation test, but only 19 used the test results alone for system sizing (6). In 1980, thiry-two states specified its use in design (7). Of these, only 7 used the percolation test exclusively (10).

In analyzing the above trends, the percolation test appears to remain extremely popular, despite its proven shortcomings. Since the test appears to be straightforward, semi-skilled technicians appear able to perform it with some reasonable level of proficiency. Despite the fact that tests have been developed which actually measure hydraulic conductivity of the soil under a variety of moisture conditions, the percolation test remains in general use because of the complexity of these other tests. Therefore, the attitude of several code-writers has been to either continue using the percolation test only as one of several data inputs to system design, or to eliminate it altogether and rely on other site evaluation data. The other data in both of the above cases include detailed soil analysis of texture, depth and structure, landscape location and drainage, and prior experience with the identified soil for on-site wastewater disposal. Fortunately the "blind" use of percolation tests for sizing of soil absorption systems does appear to be waning.

SEPTIC TANK SPECIFICATIONS

Several trends can be identified in reviewing the surveys of 1949, 1971, 1976, and 1980 (1,5,6,7). In 1949, the minimum volume for a septic tank was specified as 1.9 cu m (500 gal) by 21 of 47 states, while in 1980, 28 of 49 states required a minimum of 2.8 cu m (750 gal), and fourteen required 3.8 cu m (1000 gal) or more. With relation to other tank specifications, the 1949 survey noted that 40 states specified a minimum length to width ratio, and 72 percent of those required that ratio be between 2 and 3. In 1971, only 8 states specified a minimum length to width, and all but one required it to be 2 to 3. Similarly, of the 41 states requiring a minimum depth in 1949, 89 percent required 1.2 m (4 ft) or more. In 1971 only 22 states had a minimum depth requirement, and over half of those required a minimum depth of 0.9 to 1.2 m (3 to 4 ft). Because of its more comprehensive nature, the 1949 survey contained information on many more details of tank requirements than the subsequent surveys. It noted, for example, that six states recommended two-compartment tanks, while the author is only aware of two states doing so at present. Also, in 1949 four states recommended against inlet baffling or submergence, a nearly universal requirement today.

What do the above trends seem to indicate? Clearly, the code-makers feel that larger tanks are advantageous. However, they are becoming less restrictive on the shape of the tank. Given the reduced septic tank pumping frequency requirement of the larger tank and the concerns for both increased wastewater flow due to modern plumbing fixtures and widespread use of garbage grinders, this progression would appear to be logical. However, earlier intent to improve tank performance through better internal design has apparently given way to perceived benefits of larger tanks.

Areas of discussion over the years with relation to materials of construction, inlet structure design, area to volume ratios, baffles vs. tees for outlets, outlet deflection baffles, and compartmentalization are not covered in the three most recent surveys, but review of more than one state code will reveal some variation in these factors, where specified.

SOIL ABSORPTION SYSTEMS

Since the 1949 survey (1) and publication of the Manual of Septic Tank Practice (MSTP) (4), the emphasis of codes has shifted from the pretreatment, e.g., septic tank, to the soil absorption systems (SAS). This trend has been quite logical given that an SAS is the normal site of failure and failures are not necessarily related to pretreatment. Therefore, the SAS specifications of state codes have been the primary area of revision where excessive failures have occurred in systems which ostensibly have met code requirements.

SAS geometry has been a subject of considerable debate for decades (11). At the root of the debate is the argument of bottom vs. sidewall infiltration rates. In areas where soil moisture is normally quite low and groundwater has little influence, it would be expected that trench bottoms of conventional gravity-fed systems would be likely to reach their equilibrium clogging condition first due to the wetting conditions and gravitational forces in the trenches. However, with additional time, the sidewalls would also be expected to equilibrate in a similar manner starting from the bottom upward. Once an equilibrium condition is established in a continually ponded trench, the bottom area could infiltrate at a higher unit rate due to a greater gravity head. A variety of different soil, climatic, hydrologic and design loading conditions could result in the beneficial use of either shallower or deeper trenches.

In 1949 the modal minimum trench width for 27 states was 18 inches, while in 1980 is was 12 inches. However, of 22 states included in both surveys, 16 changed their requirements over that period, but 10 of those increased the minimum width, and only 6 decreased it. Since the average reported minimums for both surveys are about 18 inches, these dimensional requirements offer little insight as to any changing trends with regard to bottom vs. sidewall infiltration.

The 1949 survey did not note any minimum trench depth requirements, but the 1971 survey noted that 17 states did require it. Of the seventeen, 12 required a 24-inch minimum, while all but one of the rest required a lesser minimum depth. In 1980, twice as many states required a minimum depth, with a modal requirement of the same 24 inches. Only 5 states required a greater minimum depth. Although modes and averages and the number and direction of changes were minor in this period, the potential danger of the significant increase in the number of states requiring a minimum depth is that it restricts the use of potentially valuable shallow trenches where local conditions are favorable to their use. Likewise, the 1980 survey indicated that 28 states have a maximum depth requirement, which could potentially stifle use of deep trenches in areas where their use might be advantageous.

One very drastic change in trench requirements is in the minimum cover required over the trench. In 1949 half of the codes surveyed cited a "preferred" cover of 45 cm (18 in.), while in 1980 more than half of the states required only 15 cm (6 in.). Clearly, the oft-stated concern for freezing and mechanical damage has diminished, and possibly, some attempt to more effectively use evapotranspiration assistance in disposal may be apparent.

The spacing between trenches has been specified by most states for several decades. According to Machmeier (12) the basis of this requirement relates to the design of construction equipment to permit easy access and avoid disturbing infiltrative surfaces. Unless the space between the trenches is designated by a SAS replacement area, required by 21 of 45 states in 1980, equipment requirements would not require a spacing of more than 4.5 feet (12). The hydraulics of flow from trench sidewalls in non-sandy soils has not been applied to spacing requirements, but it would be expected to vary significantly.

In the 1949 survey the average minimum trench spacing requirement of 33 states was 7 feet, while in the 1980 survey 44 states had an average minimum of 6 feet. Of 28 states included in both surveys, 15 reduced these minimums while only 4 increased them. All of the latter four states had originally required spacing of 4 feet or less. It would appear that the trend has been toward reduced spacing sufficient to accommodate construction equipment, which also maximizes the number of trenches and wastewater absorption per unit area of land.

Of course the ultimate practical objective of the SAS is to dispose of wastewater in a manner which results in neither surfacing of the wastewater nor groundwater pollution. To prevent the former the system must provide sufficient infiltrative surface to accept all the wastewater received from the home. Therefore, an analysis of design loading requirements is necessary.

Design loadings determined in the 1949 survey were expressed in a variety of ways in different states. For example, some codes expressed required soil absorption in trench bottom area per capita, while others employed length of trench per capita and bottom area per bedroom. Without other specific details

of the various codes direct comparisons are impossible. A few noteworthy items included the general agreement that clays were unsatisfactory for soil disposal and the absorption area requirement range of from less than 100 sq ft for sandy soils to 1000 sq ft for the finest-textured acceptable soils. In those states which had already encoded the percolation test in 1949, absorption area requirements had doubled by 1971 for sandy soils along with significant, but smaller, percentage increases for finer-grained soils with marginally acceptable percolation times. With regard to very permeable soils, the 1976 survey showed nine states with minimum SAS sizes. The 1980 survey indicated that this number had grown to 29 states, but that the minimum sizes varied widely, from 70 sq ft to 500 sq ft, with a mean minimum size of 175 sq ft.

The obvious conclusion is that the required sizing of conventional soil absorption fields has generally increased between 1949 and 1980. The reason for these increases are probably due to unsatisfactory performance of earlier, smaller systems. Given the apparent lack of understanding of the design and functioning of the SAS and its uncertain relationship to the percolation test, the logical choice was to increase the required absorption area. Numerous studies have shown that equilibrium rates of infiltration do occur with time. It is feasible that larger and larger systems could eventually permit longer system service life. Such reasoning, however, neglects two important factors. The first is economics, which includes not only the extra cost of construction of a larger SAS, but also, when combined with required setback or separation distances, the cost of larger parcels of property to permit construction of these systems. The second factor is purification of wastewater to protect groundwater from contamination. Without control over the method of wastewater application, the potential for

groundwater contaminaion is high during the early stages of operation, and this period of high contamination potential is merely lengthened by larger systems without some form of improved wastewater distribution.

The two aspects of codes which deal with groundwater contamination are the vertical separation distance to groundwater and the horizontal separation of setback requirements to household potable water supplies. The vertical separation requirements provides unsaturated soil "contact time" to accomplish treatment of the wastewater before it enters the groundwater. The horizontal separation is commonly perceived to provide further treatment time in the saturated zone before any human consumption of the treated wastewater/groundwater mixture can occur.

The 1949 survey showed 34 states with vertical separation requirements varying from 0 to 4 ft, with a mode of 4 ft. In 1980, 41 states required the same range and mode, however, the average vertical separation requirement had risen from 2.6 ft to 3.0 ft. Of 20 directly comparable states, 14 had not changed their requirements, 4 increased them, and two had decreased them. Since the contact time between the wastewater and unsaturated soil is the most effective and often the only barrier against groundwater contamination, design requirements must insure that no short-circuiting can occur which would allow insufficient treatment. Bouma (9) has described the contact time concept in detail. By integration of the Darcy equation he demonstrated the need to provide a minimum of 3 ft of unsaturated soil between the trench bottom and the top of the saturated layer to maintain hydraulic acceptance rates at design equilibrium conditions. Contact times for sandy (unsaturated) soils can be determined readily through knowledge of nominal hydraulic loadings and

moisture tension conditions because of easily predictable flow in these soils. Structured soils are far more complex and often short-circuit wastewater through natural macropores or those created by roots and worms. Bouma (9) presents examples of this short-circuiting to show nominal contact time to actual contact time ratios in some soils of 23:1 or more. Therefore, the simple designation of a vertical separation distance may not ensure against the passage of pathogens to groundwater in certain soils, especially if no control of hydraulic loading is provided. However, a requirement of 3 ft or more of vertical separation would appear to be a reasonable attempt to improve purification. Unfortunately, 13 of 41 states required less than 3 ft of separation in the 1980 survey.

Horizontal separation or setback distances to water supplies, which in most rural locations are wells, also varied widely in the surveys. In 1949 the modal (17 of 32 states) setback distance required between the SAS and the water supply was 50 ft, while in 1976 it was 100 ft in 21 of 38 states. In relation to setback requirements for surface waters, both surveys indicate that modal separation was 50 ft. The water supply setback requirement increase would appear to reflect a concern for the travel of pathogens through the groundwater to a well supply. In reviewing the waterborne disease outbreak data for 1970 to 1974, Kreissl (13) noted that in all outbreaks traced to ST-SAS's, the separation distances were in excess of 100 ft. Similarly, Ford, et al, (14) statistically analyzed well contamination by nitrates in Colorado to show the probability of nitrate-nitrogen contamination (> 10 mg/l) to be 21.8 percent at 30 m (100 ft) and 9.4 percent at 61 m (200 ft). In all of these cases, the data are influenced by several factors in addition to separation distance alone. However, the mere codification of a minimum setback distance in and of itself does not insure against pathogenic contamination of wells nor does it prevent the passage of nitrates to wells and surface waters.

Several other miscellaneous factors have crept into state codes in recent years. Among them are replacement area requirements, reduced infiltrative areas for alternative pretreatment systems, and provisions for alternative systems. The 1980 survey indicated that 21 of 45 states require an SAS replacement area (generally, 100 percent of the original system area). Such requirements, without any alternating bed provisions, appear to admit both failure of present design criteria and a lack of understanding of system functioning.

In only four states included in the 1980 survey are reductions in infiltration area permitted where aerobic treatment units are employed in place of septic tanks. The maximum reduction is 33 percent in the usual range of acceptable percolation rates. In one state the allowable percolation rate is extended from 60 to 120 min/in for aerobic pretreatment. No scientific evidence supports any reductions in less-permeable soils, although some evidence does exist to support size reduction in sandy soils (11)(12).

Since all design loading rates are based on an assumed flow which is generally related to the number of bedrooms times two persons per bedroom, an interesting observation of the 1980 survey is that 19 of 33 states use 75 gal/day/capita for design, while 12 states use from 100 to 150 gal/day/capita and 2 states use 50 to 60 gal/day/capita. These values are of interest when viewed with the knowledge that actual usage averages about 46 gal/day/capita. The allowable maximum percolation rate found in the 1980 survey which permits use of conventional systems is normally 60 min/in (26 states). However, this maximum varies from 15 min/in to 120 min/in in the other states. The earlier discussion of the invalidity of the percolation test is fortified by this variability.

Another parameter identified as widely variable in 1980 is the maximum allowable slope of the land. Eight of 18 reporting states allow up to 25% slope, while 3 states do not permit systems on slopes of greater than 15 percent and one permitted construction on slopes up to 50 percent. Although 25 percent slope is usually sited as the upper limit for backhoe operation, hand-dug systems have been successful on slopes of up to 50 percent.

Provision for alternative designs has been incorporated into 48 of the 50 states codes according to the 1980 survey. However, the author is aware of alternative systems in both of the states whose codes apparently do not allow them. Therefore, the need to provide alternative systems which can overcome site restrictions which preclude conventional ST-SAS's is apparently universal.

CODE ELEMENTS AND PURPOSES

Plews (6) has presented a historical picture of state and local on-site system code development, describing their disease prevention origins and their evolution into land use controls, growth stimulation or limitation mechanisms, and other political goals.

To properly accomplish any of these goals a thorough evaluation of the proposed site is required to determine optimum landscape location, soil texture and structure with depth, groundwater and bedrock data, hydraulic conductivity data, and information on the volume and character of the wastewater to be absorbed by the soil. The ability to obtain the above data is limited in most areas of the U.S. However, some states and localities have made great advances in upgrading site evaluation through requirements that

more highly qualified personnel perform these analyses. In these instances the associated codes are less stringent, giving qualified people an opportunity to consider a variety of designs which may be optimal to each site. In the majority of states, however, less qualified personnel are employed to determine site suitability., Therefore, codes in these states are generally quite rigid, permitting minimal adjustments of designs to site-specific conditions. In many of these same jurisdictions, when a site is declared unsuitable by those personnel, professional engineers are permitted to propose designs which can overcome site limitations.

Since all codes are based on the premise of protecting public health, and since presently employed techniques of on-site pretreatment for soil disposal are not capable of ensuring complete pathogen removal, the health protection factor centers on the proper siting, design, and construction of the soil absorption system (13). The two primary routes of human disease transmission are: 1) passage of pathogens or chemical contaminants from the disposal trench downward to the groundwater, travelling therein to a point of extraction in sufficient quantity to cause disease and 2) surfacing of unpurified wastewater where direct human contact or overland runoff to improperly cased wells can occur. In order to avoid the latter, the system must be properly sited, designed and constructed to accept the entire volume of wastewater for a long period of time. To avoid the former, the system must be properly designed to avoid localized overloading and to provide sufficient contact time in the unsaturated soil zone to ensure purification.

Horizontal separation distances from water supply facilities have been increased over the past 30 years in several state codes in hopes that this increased distance would provide improved protection against contamination by overland flow of surfacing effluent and by subsurface flow of contaminated groundwater, should these forms of failure occur. In both cases, some advantage is gained through increased distance, but the probabilities of pathogen transport and survival remain quite real. The most effective protection against overland contamination of wells, for example, is proper sealing of the well casing and landscape modifications which preclude or minimize the possibility of runoff from the disposal site into the well. Likewise, the best protection against subsurface contamination is the assurance of sufficient contact time in the unsaturated zone of the soil to preclude contamination of the aquifer, because certain types of aquifers, e.g., fractured limestones, offer little purification potential-other than dilution and die-off of pathogens.

A codified vertical separation between the trench bottom and the high seasonal groundwater level does not ensure the necessary contact time. Vertical macropores from root channels, worm activity, or natural structural phenomena can allow short-circuiting of pathogenic organisms through the intervening zone. Intelligent site evaluation will enable identification of these conditions. Regulatory agencies may then provide for alternative designs, such as pressure distribution or protective sand layers, to minimize the potential dangers of these conditions where aquifer characteristics and use dictate these protective measures.

DISCUSSION

State codes dealing with onsite wastewater treatment and disposal systems are dynamic and have generally undergone significant change in the three decades chronicled by four nationwide surveys. The changes, however, generally lag technology advances by several years, possibly due to a lack of a significant number of water-borne disease outbreaks clearly traced to code shortcomings. As Plews (6) pointed out, the time lag or deviation from the technological state of the art can also be due to political pressures. With improved site evaluation capability and the array of alternative technologies now available to provide acceptable sanitation for almost any site, use of flexible guidance criteria in place of restrictive codes is feasible. For example, in the State of Maine, much of the old traditional code was abandoned in 1974 due to an inordinately high failure rate for onsite systems. By implementation of licensed site evaluators who are trained and monitored by the State Department of Human Services to provide comprehensive soil evaluations prior to system identification, design and installation, the malfunction rate has become insignificant (15). A related consequence of this program has been the use of the qualified feedback from these evaluators to revise important design parameters, such as design loading rates.

Other states, such as Oregon and North Carolina, have also been undergoing significant changes, including an increased emphasis on qualified site evaluation. The conclusion that one can draw from the above examples, is that there is less lag time between technology advances and code changes, due to increased flexibility, in states where management of onsite wastewater systems has improved through upgrading of staff capability, training programs, and monitoring/feedback/technical assistance programs.

The corollary of the above conclusion suggests that those states whose codes are inflexible and stable are most in need of reviewing their management structure and codes in light of today's technologies. This does not imply that a change of code is the same as progress, for many ill-advised changes have been made in codes over the last 30 years. It actually suggests that code changes should be based on intelligent examination of experience, which requires a management structure capable of evaluating experience data in the proper theoretical context and subsequent revision of codes to reflect those verified data.

SUMMARY

State codes pertaining to regulation of onsite wastewater treatment and disposal systems have been shown to reflect several, but varying, trends over the past three decades. Several of the codified requirements have been reviewed to show the trends of these changes and their physical significance. The technical, political and management implications have also been discussed.

REFERENCES

1. Weibel, S.R., Straub, C.P., and Thoman, J.R., Studies on Household Sewage Disposal Systems (Part I), Federal Security Agency-Public Health Service (1949).

2. Bendixen, T.W., Berk, M., Sheehy, J.P., and Weibel, S.R., Studies on Household Sewage Disposal Systems (Part II), Federal Security Agency-Public Health Service (1950).

3. Weibel, S.R., Bendixen, T.W., and Coulter, S.A., Studies on Household Sewage Disposal Systems (Part III), U.S. Dept. HEW-Public Health Service Publication No. 397 (1954).

4. Manual of Septic Tank Practice, USPHS Publication No. 526 (1957).

5. Patterson, J.W. Minear, R.A. and Nedved, T.K., Septic Tanks and the Environment, NTIS Report No. IIEQ 71-2 (1971).

6. Plews, G.D., "The Adequacy and Uniformity of Regulations for On-Site Wastewater Disposal-A State Viewpoint," in National Conference on Less Costly Wastewater Treatment Systems for Small Communities, USEPA(1977).

7. Virginia Department of Health, Survey of State Regulations in 1980, unpublished.

8. Bouma, J., "Evaluation of the Field Percolation Test and an Alternative Procedure to Test Soil Potential for Disposal of Septic Tank Effluent," in Soil Science Society of America Proceedings, 35, No. 6 (1971).

9. Bouma, J., Soil Survey and the Study of Water in Unsaturated Soil, Soil Survey Paper No. 13, The Netherlands Soil Survey Institute (1977).

10. Ward, R.C., "Alternative Management Strategies for Colorado's Small Wastewater Flows," in 4th Workshop on Home Sewage Disposal, ed. by R.C. Ward, Colo, St. Univ. Information Series No. 45 (1981).

11. Otis, R.J., Plews, G.D., and Patterson, D.H., "Design of Conventional Soil Absorption Trenches and Beds," in Proceedings of 2nd National Home Sewage Treatment Symposium, ASAE Pub. No. 5-77 (1978).

12. Machmeier, R.E., "Design Criteria for Soil Treatment Systems," Presentation to ASAE, ASAE Paper No. 75-2577 (1975).

13. Kreissl, J.F., "Current Practices-Subsurface Disposal," in Proceedings of Conference on Microbial Health Considerations of Soil Disposal of Domestic Wastewaters, ed. J.W. Canter, under EPA review for printing (1982).

14. Ford, K.L., Schott, J.H., and Keefe, T.J., "Mountain Residential Development Minimum Well Protective Distances vs. Well Water Quality," Jour. of Envir. Health, 43, No. 3 (1980).

15. Moreau, E.M., "Failures-Remedies and Prevention," Paper presented to Eighth Individual Onsite Wastewater Systems Conference, Ann Arbor, Michigan (1981).